Amendments to the Specifications: (Marked-up copy)

BACKGROUND OF THE INVENTION

Please replace paragraph [0001] with the following amended paragraph:

[0001] ~~Cyclo torque multipliers in machine tools, specifically robots, still fail prematurely today. Robots are still badly hampered by harmonic vibrations and insufficient rigidity. The life of many cyclo gears is short as is the case with machine tools, too.~~ This invention addresses geometric relationships and designs and the problems that occur with cyclo torque multipliers. Some of those problems are harmonic vibrations (See attached Charts 1 and 2.) and insufficient rigidity which are eliminated with the features described in this patent.

Please replace paragraph [0002] with the following amended paragraph:

[0002] ~~FIGS. 1-5 drawings explain how, by the use of these geometric design arrangements and relations, a much higher mechanical rigidity, life expectancy, and applicability of cyclo gears is accomplished. These designs incorporate bearing and hub-axis, hollow centers and hollow torque pins, especially with three disks and three cam cyclo gear arrangements. These inventions simplify the building of machines, particularly when multiple axes are used in sequence, as in base turn tables and arm and wrist assembly clusters for robots and other tools. A true roll-up by maximum engagement of the cyclo components is guaranteed by employing the geometrical relations shown.~~ Drawings in Figure 1 (1.1 through 1.11) and Figure 2 (2.1, 2.2, 2.3) show that if the geometric design relations noted in Table 2 are used, a much higher mechanical rigidity, longer gear life, and easier use and application of cyclo gears is accomplished. The most obvious feature is a deeper tooth engagement. The result is a direct force contact. These

designs incorporate cyclo-bearing hub-axes with hollow shafts and hollow torque pins. These inventions simplify the building of machines, particularly when multiple cyclo axes are used in sequence, as with base cyclo turn tables and waste and cyclo arm-wrist assembly clusters for robots and other frequently-linked tools. With these cyclo inventions, a more direct and deeper, three-vector multi-line engagement of the cyclo components is guaranteed. Therefore, variable load vectors are controlled and neutralized, and they will not generate harmonic vibrations.

Please replace paragraph [0003] with the following amended paragraph:

[0003] ~~The FIG. 6 schematic shows the simplification of the absolute encoder system for servos in machine tools and robotics.~~ Figure 3 depicts an electrical circuit that is a smoothening, anti-oscillating add-on filter for servo systems. Attached Charts 1 and 2 show oscillation and vibrations that can be reduced electronically with this smoothening circuit by applying this patented control technology whose results are explained and shown graphically in Figure 4.

Please replace paragraph [0004] with the following amended paragraph:

[0004] ~~The FIG. 7 circuit is the smoothing, anti-oscillating add-on filter for servo systems in machine tools and robotics.~~ The Figure 5 schematic shows the invention of a constantly powered absolute encoder system for controlling a complete servo cyclo axis. It is a single two-channel disk encoder with quadruple (exclusive "or" gate) up/down counter that is both backlash free and directly coupled to motor and cyclo axis, as well as to the program controller - computer.

BRIEF DESCRIPTION OF THE DRAWINGS

Please replace paragraph [0005] with the following amended paragraph:

[0005] ~~FIG. 1 invention drawings explain the basic geometrical relationship of the "cyclo-module" to the cyclo housing/roller cage, the cyclo wave disk, and the cam/eccentric dimensions. These geometrical design relations and the realized simplifications are the basic features of these inventions.~~ Figure 1, Table 1, lists the key parts of the three-disk cyclo gear axis invention. The accompanying drawing, Figure1.1, explains the basic design of the cyclo gear axis in cut view through the center of the assembly.

Please replace paragraph [0006] with the following amended paragraph:

[0006] ~~In FIG. 2, the basic cyclo torque multipliers are drawn with one, two, and three wave disks--shown in both front and cut views. The six drive-out pins kept in the drive-out flange within a capturing flange, bearing, and housing arrangement are improvements here. The cyclo torque multiplier with the three wave disks is new, and it is the least prone cyclo gear to load deflection. The two wave disk cyclo torque multiplier is somewhat open to outside load behavior. The least rigid and unbalanced cyclo torque multiplier has only one wave disk, and it is only recommended for miner low speed applications.~~ Figure 1.2 shows the cyclo gear axis with one sun and three planet gears that timely drive the three eccentrics and cyclo disks. Also revealed in the two drawings, Figure 1.1 and 1.2, are three hollow eccentric shafts, one hollow center shaft with sun gear, and three additional passageways in the containing flange. There are also six threaded fastening holes on each side of the axis for tying this axis to other machine units. There are twelve taped holes in the ID-Gear housing for fastening the high torque

flange to other machine parts. In total, the drawings reveal seven hollow channels in the patented cyclo gear axis design.

Please replace paragraph [0007] with the following amended paragraph:

[0007] ~~The circular relationship of cams and disks is given at 360 degrees divided by the numbers of the disks. For instance, 2 disks are 180 Degrees apart, and 3 disks are 120 degrees apart.~~ Figure 1.3 shows part numbers 4, 5, and 6 in cut view. This design allows the hallow channels that are an integral part of these inventions.

Please replace paragraph [0008] with the following amended paragraph:

[0008] ~~The FIG. 3 cyclo gear torque system has three camshafts, three wave disks, three through-mounted (hollow) torque rods, three planet gears, and one sun gear. This is the most accurate and responsive design arrangement in cyclo gears. The two main bearings support the drive-outs and act as axis bearings. Significantly new is that the input camshafts are in use for the drive-out torque force coupling, providing a play-free high torque connection and transfer. The cyclo gear is also a complete axis. Applying precision manufacturing tolerances, the response hysteresis of this design is practically zero. A zero backlash is relevant in many applications and this cyclo design fits this label.~~ Figure 1.4 shows, in cut view, the assembled parts numbers 2, 3, 7, 8, 9 as they are being inserted into part number 1, which is the gear housing shown in Figures 1.5 and 1.6.

Please replace paragraph [0009] with the following amended paragraph:

[0009] ~~In FIG. 4, the heavy-duty precision cyclo gear system is identical with the one in FIG. 3, except all components are stronger for heavy-duty application. It also includes~~

~~one outer-center peripheral sun gear for a side-in drive and a space for a lead-through drive shaft, coaxial shafts, or a path-through cable.~~ Figure 1.7 is identical to Figure 1.1. This Figure is shown side by side with Figure 1.8 to depict the three cyclo disk engagements that ensure equalized force distribution.

Please replace paragraph [0010] with the following amended paragraph:

[0010] ~~In FIG. 5, a center-driven cyclo gear-axis is the economic cyclo-axis system which uses compact needle-roller bearings for total compact design. The torque bars may also be made hollow for lead-through shafts, cables, etc. The centered cam-shaft may be maximized and additionally hollowed for coaxial shaft application.~~ For clarity and simplification, Figure 1.6 shows a one cyclo disk engagement.

Please replace paragraph [0011] with the following amended paragraph:

[0011] ~~In FIG. 6, the battery power-backed, transistor-to-transistor logic, two channel single rotation encoder system, replaces what is currently used (i.e., the costly two-scale counter encoder servo systems with two encoders, four channels, with one channel revolution counter and anti-backlash gear down-gearing system for absolute position encoding). With this new constantly "ON" low-powered battery-backed encoder system, the rotation position is always known after the original position calibration, even when the main power is off and disconnected, as long the battery is powering the encoder. The battery power should supply the encoder system for five years (per recommendation of this inventor). A low battery voltage system indicator and system disabler is incorporated for safe operation~~. Table 2 clarifies the cyclo gear relations and symbols. In this cyclo gear system, the gear teeth are round. The center of each tooth lays on the gear's true rollup diameter as shown in Figure 1.9.

- D1 is the roll diameter of the cyclo gear.

- D2 is the roll diameter of the cyclo disk.
- Z1 stands for the amount of cyclo gear teeth (always a whole integer).
- Z2 stands for the number of cyclo disk teeth and is one less than Z1 here.
- R stands for the tooth radius.
- r stands for the arc – radius, generated by tangent of R, R, and D2.
- O stands for the offset of the eccentric and is dimensioned as O= R/2.
- e stands for the angular index of the offset and here is 0, 120, 240 degrees.

Please replace paragraph [0012] with the following amended paragraph:

[0012] ~~The schematics in FIG. 7 shows one add-on harmonic damping filter for analog electronic feedback loops. It is desirable to increase the life of components by reducing or eliminating harmonic vibrations. This filter is very easy to apply and very effective in improving life and performance of machine tools and cyclo gears. It filters and impedes vibration.~~ Variable load deflections do influence cyclo gear engagements. However, with three disks in constant engagement and zero play and backlash between eccentrics and cyclo teeth, motor and encoder, a vibration induced by the servo and cyclo gears is not possible. The vibrations shown in Charts 1 and 2, therefore, are not possible with these cyclo axes designs. This patented cyclo gear axis velocity Chart is a straight parallel line to the time "t" line.

Please replace paragraph [0013] with the following amended paragraph:

[0013] ~~The invention cyclo torque multiplier, FIGS. 1-5, are mostly used in robotics manipulators, tooling, and production machines, etc., which are driven by electric or hydraulic servo motors for vibration-free movements, positioning, and indefinite programmed or adaptive positioning. FIGS. 6 and 7 apply to the servo control part in~~

~~connection with the cyclo torque multipliers.~~ Table 3 shows samples of cyclo relations starting with only three teeth up to 61 teeth. Gear ratios up to 500/1 are recommended with the Figure 2 type cyclo design and 1500/1 with fore-set planetary gear as in the Figure 1 type cyclo design.

Please replace paragraph [0014] with the following amended paragraph:

[0014] ~~The basic geometrical relations are given in FIG. 1 along with the relations of the cyclo-module. The cyclo-module relates to the roller size and spacing, the diameter pitch, the roll-up dimension, the roller spacing, the cam offset size, and the cyclo wave disk dimensions.~~ Figure 1.11 shows how this geometrical system fits together and how easily it can be expanded. It is an economic and ridged high torque system that fits low, medium, and high lot manufacturing technologies such as casting, powder metal pressing, stamping, and CNC manufacturing.

Please replace paragraph [0015] with the following amended paragraph:

[0015] ~~In FIG. 1 (#1.1), the cyclo housing carries the slip-fitted rollers (#1.3). The wave disk(#1.2) is mounted concentric with bearings to the cam (#1.4). The high torque drive out is accomplished with the pins and bearing bushings (#1.5). The drive-out pins are press-fitted into the drive-out flange.~~ In Figure 2, the basic cyclo torque multipliers are drawn with one, two, and three wave disks. There is only one centered eccentric driving shaft. But there are six hollow drive-out pins with sleeves kept between in the drive-out flanges. The hub-axis, bearing and housing arrangement are improvements here. The cyclo gear and cyclo disks and their relations are identical to the one shown under Figure 1. The expandability of the cyclo axes design is featured here again.

Please replace paragraph [0016] with the following amended paragraph:

[0016] ~~FIG. 2 shows the cantilevered pin drive-out cyclo torque multiplier assembly with one, two, and three wave disks (#2.2 cut views) and cam with bearings (#2.4). The drive-out pins are press-fitted into the drive-out flange (#2.10) that transmit the high torque generated by the crank's rotation. The cams do engage the wave disks with the rollers. The rigid center location of the cam shaft to the roller cage housing, the drive-out flange (#2.10), bearing (#2.6), sides housing (#2.8), and cycle housing/roller cage, is secured here.~~ The radial eccentric index (e) is given at 360 degrees divided by the numbers of the disks. For instance, two disks are 180 degrees apart and 3 disks are 120 degrees apart.

Please replace paragraph [0017] with the following amended paragraph:

[0017] ~~FIG. 3. The precision cyclo gear system and torque multiplier assembly shows the drive-out pins (#3.5) do rigidly connect the two opposing drive-out flanges. The contained force generating by the input torque by way of one sun gear (#3.9), three planet gears (#3.10), and three cams (#3.4) rotate wave disks (#3.2) around counteracting rollers (#3.3) and the cyclo housing/roller cage (#3.1). The cams (#3.4) and wave disks (#3.2), by way of play free bearings, transmit the output torque to the high torque output flanges.~~ The schematic in Figure 3 shows one add-on harmonic damping filter for the analog electronic velocity feedback loop. It is desirable to increase the life of servo components by reducing or eliminating harmonic vibrations. This filter is very easy to apply and is effective in improving life and performance of machine tools and cyclo gears. It filters and reduces vibration.

Please replace paragraph [0018] with the following amended paragraph:

[0018] ~~The output torque=0.98.times.1/i.times.input torque. These systems are very effective.~~ The results of the frequency shift filter of Figure 3 schematics are shown as trace curves in Figure 4. Considering any velocity vibrations, the high amplitude spikes will be countered by attenuating and delaying the velocity signal to work against the periodic movements. This is called oscillation and velocity vibration damping by electronic means. This is an active countermeasure and is part of these inventions.

Please replace paragraph [0019] with the following amended paragraph:

[0019] ~~The hollow center (#3.11) make coaxial lead through possible. The three hollow drive-out pins (#3.5) allow the lead through of cables, shafts, etc. Because of the two-bearing system, the radial and axial loads can be higher as in the loads of a cantilevered system. The rigidity of this system is so high that harmonic oscillation is eliminated. Or, if brought in by the input rotation, they are reduced by the total linear gear ratio of the system.~~ Figure 5 shows the schematics of the battery power back-up transistor to transistor logic with two-channel single disk quadrupling encoder up/down counters. It will replace what is currently in use which is an assortment of different geared disk encoders with a multitude of counters. With this new invention which is a constantly "ON", low-powered (infrared) battery-backed encoder system, the rotation position is always known even when the main power is turned off, lost, or interrupted, as long as the battery is powering the encoder. The battery power should supply the encoder and counter for a minimum of five years. A low battery voltage interlock is mandatory.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Please replace paragraph [0020] with the following amended paragraph:

[0020] ~~FIG. 4. This precision cyclo gear system is basically similar to the previous one shown under FIG. 3 except it is the heavy duty version of it. It also shows how a peripheral planetary sun gear may be used for driving it on with a timing belt, etc. The heavy duty cyclo gears may be used for turn tables, out-layer arms, etc. The easy use is accomplished because it is a backlash free cyclo gear axis with four lead through opportunities, one center (#4.11) and three hollow torque rods. When extremely high loads need handling, roller, and cross roller bearings (#4.6) will be incorporated.~~ The cyclo torque multipliers and controls are used in robotics manipulators, tooling, and production machines and in many industries. They are basically powered and driven by electric or hydraulic servo motors for doing work, such as positioning and flexible programming to do adaptive moves and locating.

Please replace paragraph [0021] with the following amended paragraph:

[0021] ~~FIG. 5. A most economic heavy duty cyclo torque axes with one center driven cam shaft (#5.4) and six hallow torque pins and needle bearings (#5.5) is the most compact and rigid. The axes bearings (#5.6) are deep groove ball bearings. As with all the other cyclo gear torque multipliers, the three wave disk (#5.2) system is the most vibration free system. All shafts are sealed with lip seals to allow semi liquid lubrication for a long gear life.~~ Since the invention of the wheel, man has unsuccessfully tried to understand and document all important geometrical relations of the cyclo drive. The inventor of this patent has achieved the simplification of the cyclo gear with all the necessary geometrical relations as shown in Table 2. Important features are the depths of the gear contacts, overall engagement and tooth spacing.

Please replace paragraph [0022] with the following amended paragraph:

[0022] ~~FIG. 6. This schematics shows the invention of an inexpensive absolute rotating encoder or shaft encoder. With the rechargeable battery (#6.4) the LED (#6.2) generates a light beam. The angular rotation encoder (#6.1) has transparent circular windows that let the light path through or stop it. The light will trigger the photo-transistors (#6.3) ON and OFF, making square pulses in the channel A and B. If the Channel A pulse is leading, the up-counter is counting with increasing counts. If the Channel B pulse is leading, then the down-counter is decreasing the counts. The counts represent an axes or gear positions in machine tools, robots, etc. The shift register (#6.5) allows a computer, for instance, to access the counter data for position verification on start up, during calibration of the axes, etc. Because the battery recharges when the machine is powered and the counter is in use, the battery is powering the counter at all times. This arrangement constitutes an inexpensive absolute counter. This system reduces the absolute encoder cost by about 65%, and increases the absolute encoder reliability by a minimum of 300%, because of fewer components in use.~~ The cyclo module is the radius of the cyclo tooth or roller radius. The gear pitch diameter is the cyclo-module times the number of teeth and it represents the roll-up diameter. The arc roller spacing is also the diametrical pitch. The eccentric offset size "O" is the cyclo module "R" multiplied by 0.5.

Please replace paragraph [0023] with the following amended paragraph:

[0023] ~~FIG. 7. This circuit is a smoothing, anti-oscillating add-on filter for servo systems. Inertia, imbalance, and manufactured imperfection, influence rotating shafts, gears, and machine elements. This imperfection quite often shows up as vibration and oscillation. Servo drives, because of the feedback, stimulate the vibration especially if the servo response is working in a high-gain mode. To minimize or eliminate this problem, the add-on-filter for servo systems was invented.~~ Figures 1.1 through 1.8 show how the eccentric

shafts, with the bearings and the flanges, together with the cyclo ID-Gear housing, generate high torque. Because of the three cyclo disks and the deep and direct radial contact, the force deflection is neutralized. The shock safety load of this cyclo gear design is very high. There is practically zero load deflection because of the short drive in and drive out shafts which are supported at both ends.

Please replace paragraph [0024] with the following amended paragraph:

[0024] ~~At the #7.1 node, the servo (correctional) signal enters into the amplifiers. The undamped signal becomes the underdamped signal at the next frequency cycle, and the under-damped (#7.6) curve increases to a saturation point. At node #7.2 (based on the R1, C1 time constant), a shift and an attenuation of the signal will occur. At node #7.3, the feedback signal (coupled by C1 and the R2, R1) is further damped. The damping curve (#7.7) is most desirable. The highly-damped curve (#7.8) is more easily tuned up than the curve (#7.7) for a more specific application.~~ The output torque equals 0.98 x gear-ratios x input torque. This cyclo gear axis efficiency is very high 98%.

Please add the following new paragraphs after [0024]:

[0025] The large hollow eccentric shafts make coaxial lead-through possible. The seven hollows allow passing through of cables, shafts, etc. Because of the two bearing supports of the axis system, the radial and axial loads can be much higher as in cantilevered drive-out cyclo systems.

[0026] The Figure 3 circuit is a dampening anti-oscillating add-on filter for servo systems velocity signal. Inertia, imbalance, cantilevered drive-out, one and two disks cyclo systems without bearing support, and manufactured imperfection influence rotating

shafts, gears, and machine elements. These imperfections quite often show up as vibration and oscillation. Servo drives, because of the feedback, and the phase delays stimulate vibration especially if the servo response is working in a high-gain mode. To minimize or eliminate this problem, the add-on-filter for servo systems was invented.

[0027] At Figure 3, the servo correctional signal enters the servo amplifier. Without the servo filter one of the following signals becomes an under-damped signal, as shown in Figure 4. But with the servo frequency and damping filter installed, the Figure 4 signal looks like the critically-damped signal. Connecting the servo Amplifier Output to C1, an added delay will be added and the trace will look like the critical-damped and delayed signal. Without the Figure 3 frequency shift and damping filter, vibrations shown in Chart 1 and 2 are standard. However, the cyclo axes inventions shown here, together with the servo filter and absolute encoder system will perform smoothly for many productive decades.

[0028] The Figure 5 schematic shows the invention of the new absolute rotating encoder. The rechargeable battery will power the LED and will emit a light beam. The angular rotation encoder has transparent slot windows that let the light path through or stop it. The light will trigger the photo-transistors ON and OFF, making electric square pulses in the channel A and B. If the Channel "A" pulse is leading, the up-counter is counting with increasing counts. If the Channel "B" pulse is leading, then the down-counter is decreasing the counts. The counts represent an axis or gear positions in machine tools, robots, etc. The shift register allows a computer, for instance, to access the counter data for position verification. The battery is charging when the system is powered. The battery is powering the axis counter at all times. This arrangement constitutes an inexpensive absolute counter. This system reduces the absolute encoder cost noticeably and increases

the absolute encoder reliability by a minimum of 1000% because of fewer components in use. The cyclo axes positioning is very reliable and completes the system.